9.5 IMPLEMENTATION OF POLARIMETRIC CAPABILITY FOR THE WSR-88D (NEXRAD) RADAR

Allen Zahrai, and Dr. Dusan Zrnic
NOAA/ERL/National Severe Storms Laboratory
Norman, Oklahoma

1. INTRODUCTION

The WSR-88D (NEXRAD) radar system is a national network of weather surveillance Doppler radars serving the National Weather Service (NWS), the Air Weather Service (AWS), and the Federal Aviation Administration (FAA). Since deployment began in the late 80's, operational utility of these meteorological radars has encouraged users' demand for additional capabilities. As the deployment phase nears completion, many parallel efforts are underway to resolve deficiencies and implement new features and enhancements.

This paper presents preliminary work undertaken by the National Severe Storms Laboratory (NSSL) to provide polarimetric capability for the WSR-88D. To implement this major enhancement without degrading existing capabilities of the radar, significant modification and redesign of the signal acquisition and processing subsystem is required. This effort presents an excellent opportunity to realize a second equally important goal; transition of the radar data acquisition subsystem to an open system environment.

Another expected outcome of this effort is the establishment of a research and development facility specifically for the WSR-88D user community. Such a national resource collocated with the extensive testing facilities of the WSR-88D Operational Support Facility (OSF) will be extremely useful in the development, testing and rapid deployment of new algorithms and enhancements for the WSR-88D.

2. SYSTEM CHARACTERISTICS

A WSR-88D radar is composed of functional groups, including a radar data acquisition (RDA), radar product generator (RPG), and one or more principal user processing and display stations (PUPs). The RDA subsystem provides real-time monitoring and control of the antenna, the transmitter and the receiver. The RDA contains a digital signal processor (DSP) subsystem for estimation of base data. As a fully coherent radar, it provides not only accurate high resolution reflectivity information, but also radial velocity and velocity dispersion.

WSR-88D radars utilize different operating modes to provide meteorological data for various atmospheric conditions. The radar uses an elevation over azimuth pedestal and continuously scans the volume of surrounding space in a so called precipitation or convective mode of either 14 or 9 unique elevation scans from 0.5 to 19.5 degrees in 5 or 6 minutes, respectively. The clear-air mode consists of 5 unique elevation scans from 0.5 to 4.3 degrees in 10 minutes. Other operating characteristics such as Pulse Repetition Frequency (PRF) and the pulse width can also be changed to improve observation of atmospheric conditions.

The RPG algorithms operate on base data to generate a variety of products for the user. Many candidate algorithms and new features have been identified but not implemented due to lack of adequate processing resources or lack of suitable implementations. In addition, several problems which contaminate WSR-88D products must be resolved in order to improve data quality and it's utilization. These problems which plague all Doppler weather radars include; range/velocity ambiguities, and contamination by ground clutter and anomalous propagation.

Implementation of certain features and resolving some of the deficiencies will require modification and/or enhancement of the signal acquisition and processing equipment in the RDA. However, the existing RDA is based on a custom signal processor and a legacy computing platform designed during the late 70's and early 80's. The proprietary nature of RDA subsystems and components make systematic replacement and incremental upgrade difficult if not impossible.

3. GENERAL REQUIREMENTS

Propelled by an increasing number of enhancements requested by the user community and concerns over premature obsolescence, a number of objectives can be outlined for the evolution of the RDA. These objectives were developed in consonance with ongoing work on the open system RPG (ORPG). Although many architectural goals adopted for the ORPG can be extended to the RDA, the open system standards can only be partially applied. There are many specialized and custom components in the RDA for which no standards exists.

In general, the goals of the open system design effort can be outlined as follows:

- The architecture must be modular and scalable. It must readily accommodate modular replacement and enhancement. The system must be able to evolve with new user requirements and modern technology.
- The system should utilize commercial off-the-shelf (COTS) hardware and open system technology to the maximum extent possible.
- Design should avoid proprietary hardware and software environments if possible. Application software should be designed to be portable at least at the source level.
- Design should accommodate interoperability between dissimilar functional modules. Incremental upgrade and

Corresponding author address: Allen Zahrai, National Severe Storms Laboratory, 1313 Halley Circle, Norman, OK 73069-8480; e-mail <Allen.Zahrai@noaa.gov>

enhancement reduces the cost and risk associated with planned product improvements.

C Reduce the overall complexity to develop new or improved meteorological algorithms, allowing rapid deployment of enhancements.

C The new architecture must provide improved maintenance and diagnostic capability. This implies an improved and more intuitive user interface for maintenance personnel.

C The architecture must accommodate fault tolerance and dynamic response to overload conditions. This implies utilization of distributed processing concepts.

C Retain as much of existing functionality as possible in order to minimize the impact to the vast existing user community.

C Retain as much of existing hardware as possible to ensure that transition and retrofit costs are manageable.

4. POLARIZATION DIVERSITY

Recent experiments with dual-polarized Doppler weather radars have demonstrated great potential in solving a variety of problems in operational meteorology. Dual-polarization technology can provide measurements of hydrometeor geometry and drop size distribution leading to possible distinction between rain, hail, and snow. Furthermore, data derived from polarimetric parameters which are immune to attenuation through heavy precipitation may lead to more accurate estimation of rain-fall rates.

To implement polarization diversity and maintain existing characteristics and capabilities of the WSR-88D a novel method has been devised in which both horizontal and vertical polarizations are simultaneously transmitted and received. Figure 1 shows a simplified block diagram of the microwave hardware configuration for dual polarized operation. Waveguide switches shown in Figure 1 allow quick transition to the original WSR-88D horizontal polarization mode. This arrangement is shown in Figure 2.

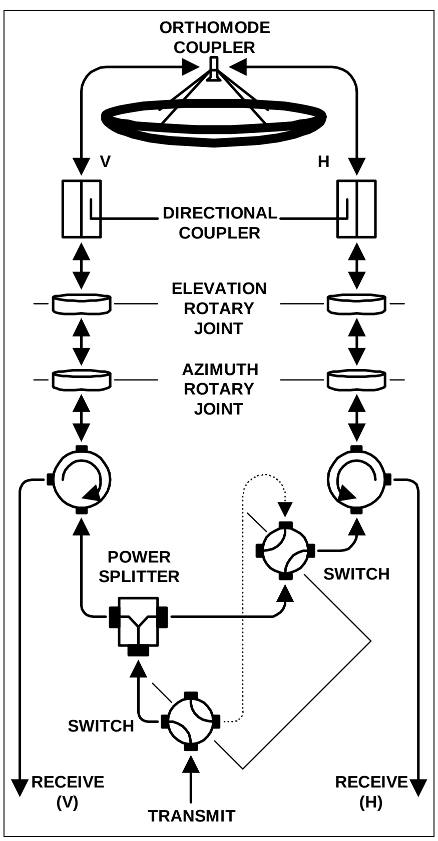

Figure 1: Dual Polarized Configuration

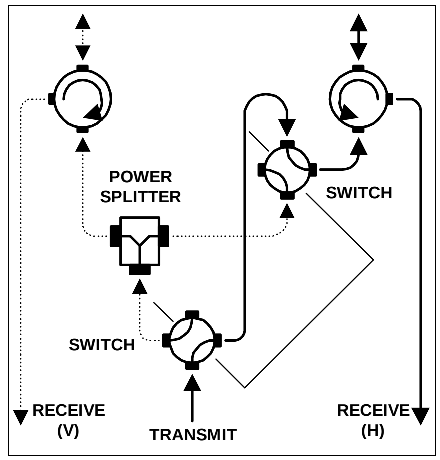

Figure 2: Horizontal Polarization Mode

Although this design requires two receivers, it provides full WSR-88D compatibility. That is, all current data acquisition modes and scanning strategies can be readily implemented, and the impact of polarimetric implementation on the existing algorithms and products should be minimal if any.

5. RDA ARCHITECTURE

The RDA is essentially a very large and extremely complex real-time monitoring and control system. Figure 3 shows a simplified block diagram of the existing RDA.

The transmitter is a coherent pulsed S-band design using a klystron tube - the only vacuum tube device in the system - to produce 750kW of power with negligible signal distortion or spurious emissions. The antenna is a 28 ft. diameter center-fed parabolic reflector with a 0.95 degree beamwidth.

The signal acquisition components consist of a receiver, a hardwired signal processor (HSP) and a programmable signal processor (PSP). The receiver uses a frequency mixer to down-convert the received signal to an intermediate signal carrier at which most amplification, filtering and gain control are performed. A second synchronous detection stage produces signal amplitude and phase proportional to the echo reflectivity and Doppler shift, respectively. For convenience, the signal is decomposed into in-phase and quadrature components and digitized for processing. The receiver uses fast automatic gain control (AGC) and provides 12-bit inphase (I), 12-bit quadrature (Q) and 6-bit AGC attenuator values at 250 meter range intervals. The HSP consists of a prescaler, ground clutter canceler and synchronization modules. The prescaler converts

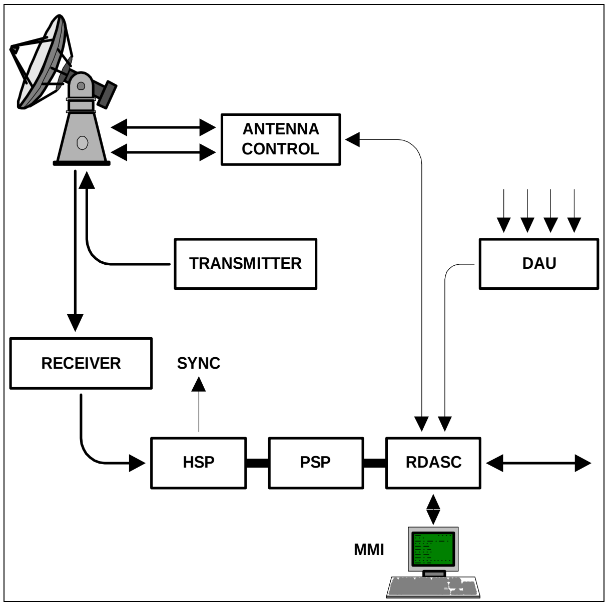

Figure 3: Simplified Block Diagram of the Existing RDA

each receiver value and the corresponding AGC attenuator setting to a valid floating point number. Each I and Q pair is then corrected to offset the amplitude and phase imbalance in the phase detector and the nonlinearities in the AGC attenuator. Following the ground clutter filters, time-series data are provided to the PSP for estimation of reflectivity, velocity and spectrum width.

The RDA status and control computer (RDASC) is the central command and control processor for the entire group. A data acquisition unit (DAU) monitors the state of all safety interlocks, power supply voltages, and environmental conditions and regularly reports to the RDASC using an asynchronous serial (RS-232) line. Servo amplifiers for the antenna are controlled by a digital control unit (DCU) which provides position information to, and receives commands from the RDASC on regular intervals.

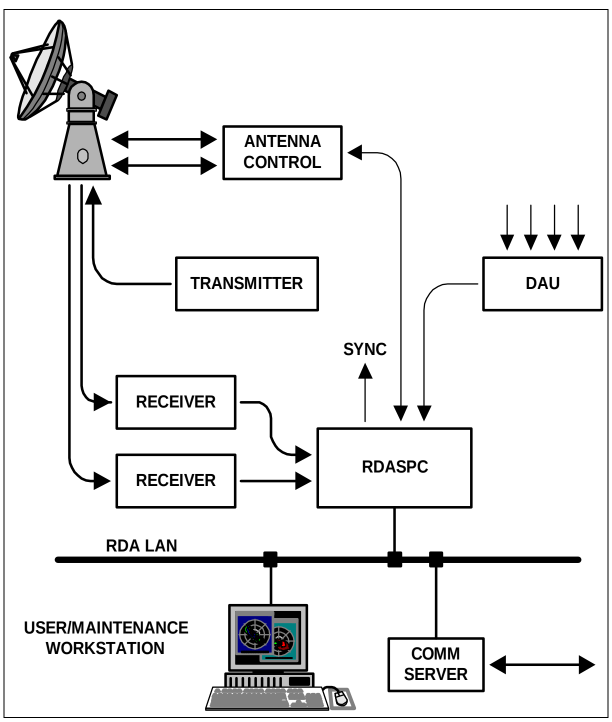

Figure 4: Proposed Architecture for the RDA

The RDA can be operated in local mode, where a terminal provides the man machine interface (MMI) functions. In this mode, maintenance functions are primarily performed. For routine operations the associated RPG provides command and control through a high-speed serial port. This connection is implemented using dedicated T1, fiber-optic or microwave communications link depending on the distance from the RPG.

In order to implement polarimetric capability and provide an open scalable RDA environment a distributed multiprocessor architecture has been adopted. This architecture - depicted in Figure 4 - essentially replaces the HSP, PSP and the RDASC with a real-time multiprocessor engine based on modern highly integrated digital signal processors (DSP) and industry standard interconnects. A typical configuration for the RDA signal processing and control (RDASPC) is shown in Figure 5. Some support functions are implied in this diagram and not directly shown.

In this design a real-time host processor controls various functional elements interconnected through a standard VME-bus chassis. A synchronization and timing module produces all required timing pulses for the transmitter and receivers including built-in test and calibration sequences. Antenna control and DAU connections are implemented with standard RS-232 ports attached to the RDASPC host.

The signal processing subsystem with its own high-speed interconnect is also integrated on the VME-bus. Data from one or more receivers are provided directly onto the DSP bus. These data streams are not provided on the VME-bus since they could easily consume available VME-bus bandwidth. The programmable DSP array performs prescaling, clutter filtering and all base data estimation algorithms. The DSP array contains enough memory to hold one or more elevation scans to enable range unfolding during the lower elevation scans, and facilitate future implementation of velocity dealiasing algorithms. The DSP array is scalable and reconfigurable. If new requirements dictate additional power, new processor modules can be added and utilized with relative ease. It provides a flexible super-pipelined super-scalar platform to exploit parallelism inherent in radar signal processing applications where the same operation is performed on different range cells. Throughput requirements are easily satisfied by using multiple buses to support many transactions concurrently.

Most modern embedded processors feature SCSI-bus and Ethernet interface. The SCSI-bus can be used for local storage and archive devices as well as standard low cost optical storage devices used for software distribution and on-line documentation. The Ethernet interface allows local area network (LAN) connectivity. In Figure 5, for example, a maintenance workstation or PC and a communications server are connected to the real-time host through the LAN. The workstation can be useful for interactive maintenance and

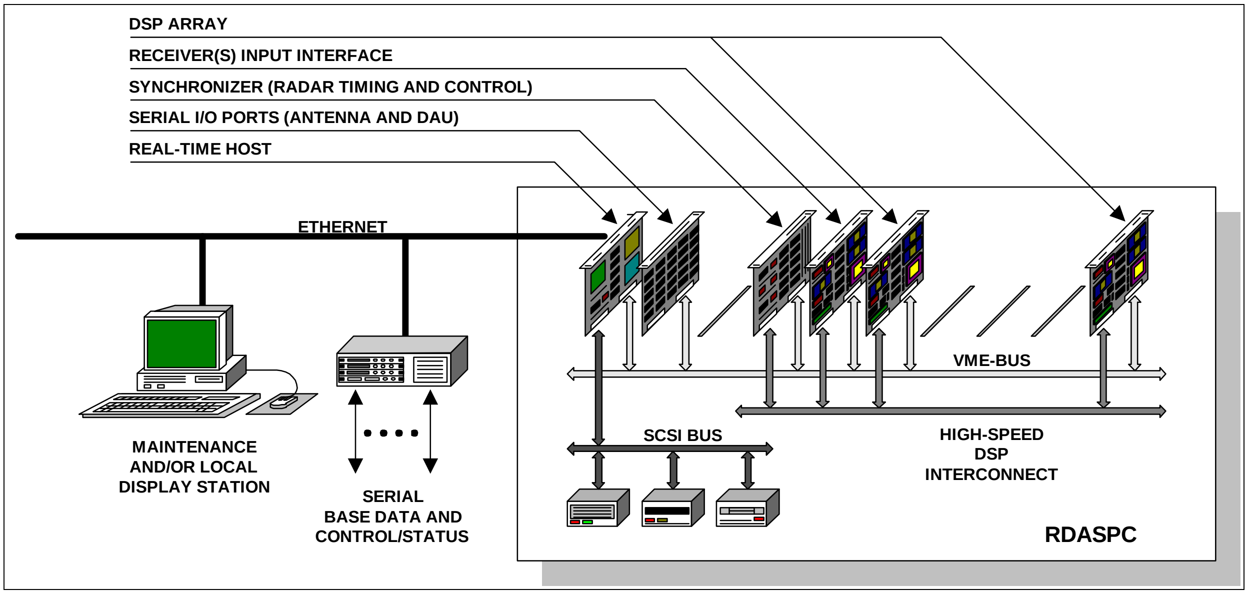

Figure 5: A Typical Hardware Configuration for RDA Signal Processing and Control

diagnostic sessions. Full or partial ORPG functionality can also be locally provided using appropriate software modules. In fact, an ORPG can be seamlessly integrated within this architecture by using common network hardware. A communications server can service a single high-speed connection to an associated RPG or support many connections as the requirements dictate.

It is important to note that many other configurations are possible within this flexible framework. System components can be modularly replaced or enhanced as the system evolves.

7. ACKNOWLEDGMENT

The WSR-88D is jointly maintained and operated by the National Weather Service (NWS), a component of the National Oceanic and Atmospheric Administration (NOAA), in the Department of Commerce (DOC), the Air Force's Air Weather Service (AWS), in the Department of Defense (DOD), and the Federal Aviation Administration (FAA) in the Department of Transportation (DOT). The primary support organization established by the three agencies is the WSR-88D Operational Support Facility (OSF). The authors also wish to acknowledge the NWS Office of Systems Development (OSD) which provides project management and support for the WSR-88D evolution. The National Severe Storms Laboratory (NSSL) of the Environmental Research Laboratories (ERL), a component of NOAA in the DOC along with the OSF and the OSD are jointly responsible for the development and testing of many enhancements for the WSR-88D. The NSSL along with other ERL laboratories provide technical leadership and guidance in further understanding and utilization of the WSR-88D system.

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